geoarchaeology workshop

Final Report

Integration of New Methods in Soils and Geomorphology Applied to Cultural Resources Management on Military Lands

sessions

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2008**	2. REPORT TYPE	3. DATES COVERED **00-00-2008 to 00-00-2008**
4. TITLE AND SUBTITLE **Integration of New Methods in Soils and Geomorphology Applied to Cultural Resources Management on Military Lands**		5a. CONTRACT NUMBER **W911NF-08-1-0479**
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Desert Research Institute - Reno,2215 Raggio Parkway,Reno,NV,89512**		8. PERFORMING ORGANIZATION REPORT NUMBER **; 54968-EV-CF.1**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **U.S. Army Research Office, P.O. Box 12211, Research Triangle Park, NC, 27709-2211**		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S) **54968-EV-CF.1**
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**32**	

Workshop participants, October 2008.

Acknowledgements

The authors would like to thank the following people and organizations for their generous and outstanding contributions to sponsoring, planning, and implementing the workshop as well as preparing the final report. First, we would like to thank the Army Research Office (ARO) and Dr. Russ Harmon plus the Desert Research Institute (DRI) for sponsoring the workshop. Second, the workshop was co-hosted by DRI and the U.S. Navy Facilities Engineering Command Southwest (NAVFAC SW). Thanks to both for their contributions. Third, Ms. Barbara Jackson of DRI was instrumental in workshop planning and working with the Bahia Resort Hotel to help make the atmosphere conducive to substantive discussions leading to productive sessions. Preparation of this report was supported fundamentally by the workshop participants who contributed to discussions both in and outside of organized sessions and provided constructive input and comments to early drafts of the report. Finalization of the report was aided by Mr. Roger Kreidberg of DRI through a comprehensive editorial review, and Ms. Lisa Wable, also of DRI, whose design and layout skills plus attention to detail led to production of this final workshop document.

on the cover

A petroglyph (rock art) in the Agua Fria National Monument with a Prickly Pear Cactus in the background. Photo credit: Bureau of Land Management, Arizona BLM Office.

Final Report

Geoarchaeology Workshop

Integration of New Methods in Soils and Geomorphology Applied to Cultural Resources Management on Military Lands

T. F. Bullard, E.V. McDonald, S.E. Baker

Desert Research Institute, Reno, Nevada

October 20-22, 2008

Bahia Resort Hotel

San Diego, California

Support for the workshop was provided by a grant from the U.S. Army Research Office

Proposal Number 54968-EVCF

I certify that funds provided by the Army Research Office under Grant W911NF-08-1-0479 were expended in accordance with the provisions of the grant and that required conference proceedings have been delivered to the Army Research Office.

acronyms

APM	Archaeological Predictive Model
ARO	U.S. Army Research Office
CRM	Cultural Resource Management
DoD	Department of Defense
DRI	Desert Research Institute
ERDC-CERL	U.S. Army Corps of Engineers, Engineer Research and Development Center – Construction Engineering Research Laboratory, Champaign, Illinois
ESTCP	DoD Environmental Security Technology Certification Program
GIS	Geographic Information Systems
GPR	Ground Penetrating Radar
ICRMP	Integrated Cultural Resource Management Plan
IRSL	Infra-red Stimulated Luminescence
LIDAR	Light Detection and Ranging
LanDPro	DRI Landscape Dynamics Support Program
MCASY	Marine Corps Air Station Yuma
NAVFAC SW	Navy Facilities Engineering Command Southwest Division
NTC	U.S. Army National Training Center at Fort Irwin, California
OSL	Optically Stimulated Luminescence
SERDP	DoD Strategic Environmental Research Program
SRLs	Segregated Lithics Reduction Locales
TL	Thermoluminescence
USMC	United States Marine Corps
USA	United States Army
USN	United States Navy
YPG	United States Army Yuma Proving Ground
XRF	X-ray Fluorescence

Petroglyphs in Sloan Canyon National Conservation Area, south of Las Vegas, Nevada. Photo credit: Bureau of Land Management, Nevada BLM Office.

contents

Petroglyphs can be found throughout the 71,000 acres that make up the Agua Fria National Monument. Photo credit: Bureau of Land Management, Arizona BLM Office.

list of participants

Name	Organization	Affiliation
Auerbach, Mike	Research Affiliate	DRI-Reno
Bacon, Steve	Research Affiliate	DRI-Reno
Baker, Sophie	Research Affiliate	DRI-Reno
Baumann, Joseph	DoD-Navy	NAVFAC SW
Becker, Mark	Contractor	ASM Affiliates - Carlsbad
Bullard, Tom	Research Affiliate	DRI-Reno
Caldwell, Todd	Research Affiliate	DRI-Reno
Cook, John	Contractor	ASM Affiliates - Carlsbad
Dalldorf, Graham	Research Affiliate	DRI-Reno
Edwards, Sue	Research Affiliate	DRI-Las Vegas
Griset, Suzanne	Contractor	SWCA
Gundrum, Darrell	DoD-Navy	NAVFAC SE
Harmon, Russell	DoD-Army	ARO
Herbst, George	DoD-Navy	NAVFAC SW - CMAGR
Jackson, Barbara	Research Affiliate	DRI-Reno
James, Karla	DoD-Army	Yuma Proving Ground
Lawson, Jan	DoD-Marine Corps	MCAS-Yuma
McDonald, Eric	Research Affiliate	DRI-Reno
McDonald, Meg	DoD-Army	Yuma Proving Ground
Morrill, Val	Consultant	private
Page, Dave	Research Affiliate	DRI-Reno
Pippin, Lonnie	Research Affiliate	DRI-Reno/Las Vegas
Ramirez de Bryson, Luz	DoD-Army	NTC - Fort Irwin
Sabol, Don	Research Affiliate	DRI-Reno
Schaefer, Jerry	Contractor	ASM Affiliates - Carlsbad
Teeter, Wendy	Research Affiliate	UCLA
Yatsko, Andy	DoD-Navy	NAVFAC SW – SCIR
Young, Craig	Contractor	Far Western Anthropological Research Group

introduction

The topic of cultural resources management (CRM) on military installations has been the subject of several Department of Defense (DoD) workshops focusing on aspects identified in the 2000 workshop sponsored by DoD Strategic Environmental Research Program (SERDP) and the Legacy Resource Management Program (Briuer et al., 2000). During the past several decades, the science of geomorphology and soils has advanced to the point of demonstrating unique and predictable relationships among landscape components—both temporally and spatially variable—and soil, hydrology, vegetation, geology, and prehistoric cultural resources. Recent research on military lands in arid regions has added further to our knowledge of soil-geomorphic processes, landscape evolution, and controls on the distribution and preservation of cultural resources. Although follow-up workshops (e.g., predictive modeling workshops of Altschul et al. (2004), Limp (2006), and Lione (2007)) addressed some of the focus areas of Briur et al. (2000), a full integration of geology and geomorphology into cultural resource management models to support the military mission has not been undertaken. Briuer et al. (2000) explored predictive modeling, remote sensing applications, and geophysical prospecting in the "Find-It" focus area, but an analytical treatment of the landscape was not a topic within the focus area despite the fact that clear relationships exist between archaeological sites and landscape components. Through prior collaborative work and discussions with cultural resource management (CRM) personnel, we perceived a need for greater communication and collaboration between geoscientists and archaeologists in a way beneficial to both disciplines. We felt that an effective starting point would be to convene a workshop aimed at addressing important issues facing CRM in the desert southwest U.S. and continuing the effort to support CRM requirements on military installations. As Briuer et al. (2000) succinctly stated, "CRM is a huge beast that is best consumed one digestible bite at a time;" we consider this workshop to be an effort to make progress in arid land geoarchaeology – another small bite into the beast.

As part of the Desert Research Institute's (DRI) Landscape Dynamics Support Program (LanD-Pro) funded through the Army Research Office (ARO), a workshop proposal was tendered to ARO. The workshop was ultimately convened on October 20-22, 2008 at the Bahia Resort Hotel in San Diego, California, and addressed scientific aspects related to geo-archaeological applications to cultural resource management on military lands in arid and semiarid environments. The workshop was

Big Rocks in the Agua Fria National Monument. Photo credit: Bureau of Land Management, Arizona BLM Office.

-The overall goal of the workshop was to examine current issues in archaeology-

sponsored by ARO and DRI and hosted by DRI and NAVFAC SW (U.S. Navy Facilities Engineering Command Southwest).

The intent of the workshop was to advance our knowledge of soil-geomorphology and landscape history as it relates to the existence, spatial distribution, and management of archaeological sites and surface features. The workshop brought together archaeologists, geoarchaeologists, geomorphologists, and military cultural resource managers to discuss current pressing issues and concerns of inventorying and managing cultural resources. Knowledge gaps were identified and shared through a series of round table discussions and keynote talks on specific topics.

This document summarizes the workshop outcome. In particular, it emphasizes important issues discussed, including current areas of research emphasis, potential new research directions, potential applications at military installations, and future plans for a working group in geoarchaeology.

workshop scope and objectives

The overall goal of the workshop was to examine current issues in archaeology and geoarchaeology, especially those relating to identification and preservation of historic and prehistoric cultural resources on military lands. This was accomplished through focused discussions between military installation archaeologists responsible for the management of cultural resources, contractors having broad knowledge and experience working in the military environment, and academic researchers engaged in geomorphic research on military lands. Specific objectives included:

1. Examine current issues in archaeology and geoarchaeology, especially as they relate to identification, inventory, preservation, and maintenance of cultural resources.
2. Foster collaboration among an interdisciplinary team of archaeologists, Earth scientists, and government agency personnel with expertise and interest in advancing the integration of soils, geomorphology, and knowledge of geomorphic surface processes with CRM in semi-arid and arid environments.
3. Identify gaps in archaeology knowledge relating to site identification, location, and distribution.
4. Discuss new strategies and technology for rapidly identifying archaeological sites, including buried sites.
5. Develop a strategy for integrating knowledge gained from soil-geomorphic and geologic research with archaeological mission objectives on military training and testing installations.
6. Develop a workshop document highlighting geoarchaeological research directions that

will benefit archaeologists and cultural resource managers in supporting the military mission and cultural stewardship on military lands.

workshop topics

A list of topical questions was circulated to potential participants for review and comment prior to and during the invitation period to help focus the workshop and discussion. The following high priority topics were identified:

- Site potential; particularly, locating and assessing buried sites
- Landform-based predictive modeling
- Distinguishing anthropogenic versus naturally-formed surface features (such as stone rings, stone alignments, geoglyphs, and intaglios)

Although not treated as specific topics, the importance of paleoenvironmental reconstruction and age control, as well as the integration of soils, geomorphic, and stratigraphic data were recurring themes throughout the workshop.

achievements and conclusions

Thirty-two people attended all or part of the workshop, which brought together CRM personnel from three branches of the military (Army, Navy, and Marine Corps), contractors and private sector CRM experts, and academicians. Three principal topics dominated the discussions; some of the topic-specific conclusions are summarized below.

Predictive modeling

- Interest is strong among archaeologists and military land managers in pursuing development and implementation of a conceptual, geomorphic-based archaeological predictive model (APM) for the desert southwest U.S.
- A multi-installation effort to produce a widely applicable model has the greatest chance of coming to fruition
- Reliable, high quality input data is necessary for successful model implementation

Buried sites

- A geomorphic-based APM for buried sites is equally attractive to cultural resource managers as is one for surface sites
- A simple conceptual model for predicting buried site locations can be based on the landform or surface age, and the energy of the depositional environment in which it formed
- Integrated depositional and erosion process models (i.e., stratigraphic and depositional models), stratigraphic data, and more complex paleo-envi-

ronmental reconstructions are essential in finding and interpreting buried archaeological sites

- Given the ability of desert pavements to heal through time, knowledge of desert pavement formation and evolution of desert pavements is critically important; knowledge of pavement formation and evolution is increasing, but a reliable method for obtaining numerical ages for pavement surfaces has yet to be developed

Surface features

- Developing criteria and protocols for distinguishing natural and anthropogenic features, especially cleared circles, is desired
- Soils and geomorphic research need to be undertaken for a range of cleared circles of various anthropogenic and natural origins

workshop sessions and discussion

The workshop was organized into discussion blocks in accordance with the three topic areas. Each discussion block consisted of paired, short presentations (15-20 minutes each) followed by one to one-and-one-half hours of group discussion. For each topic, one presentation described a geomorphic research approach applicable to geoarchaeology, and the other was based on actual CRM experience at the installation level. DRI researchers presented the geomorphic research briefings and discussion, which spanned topics such as predictive mapping, desert terrain forecasting and characterization, cleared circle studies, desert soils and geomorphology, relative age dating techniques, and coastal paleoenvironmental research relating landscape response to climate change. Department of Defense (DoD) cultural resources personnel and private sector CRM personnel provided parallel presentations on related CRM experiences. Both presentations highlighted current challenges and approaches that could benefit from application of enhanced geoarchaeological methods and techniques. The presentations and briefings set the stage for dialog in an interactive, informal, and dynamic setting. Round table discussions focused on evaluating previous and current research priorities in order to recommend future scientific research directions.

Session I

Landform-Based Predictive Modeling

Introduction to Session 1

Having access to training lands is critical to the mission of the U.S. military; federal law, however, requires the inventory of historic properties before land can be used (Section 106 of the National Historic Preservation Act of 1966 [Public Law 89-665]). Traditional

inventory methods (i.e., pedestrian survey) are time- and labor-intensive, leading to a backlog of areas in need of survey. One solution to this problem is to increase survey efficiency by focusing survey efforts on areas of high cultural resources potential, and reducing the amount of time that is spent surveying areas with low potential. This could be achieved by implementing an APM consisting of a database or model that relates cultural resource parameters with quickly observed or surveyed land characteristics—typically environmental and/or geological—to enable the site potential of locales to be predicted and ranked based on their environmental characteristics or geological setting. Supporting this notion are conclusions reached in a DoD-sponsored workshop on predictive modeling and cultural resource management on military installations (Altschul et al., 2005). That workshop recognized the absence of, and need to include, geomorphology and soils in predictive models for purposes of identifying portions of the landscape susceptible to erosion and deposition, determining age of surfaces, defining potential buried site locations, and identifying potential quarry sites.

Questions posed to the 2008 workshop participants on the topic of predictive models included:

- Is there a desire or demand for predictive models? Do cultural resource managers believe that APMs would be useful tools?
- Where and how can soils and geomorphic data enhance predictive modeling?
- What geomorphic concepts could be implemented and where?
- How can transfer of this method be achieved?
- Would better landform and soils maps help? What improvements are needed?
- How important is it to establish the connection between cultural resource sites and their geomorphic setting (as opposed to their physical setting)?
- What level of knowledge or expertise is needed to evaluate the geomorphic processes affecting site integrity and site potential?

Session I, Presentation 1

Identifying geologic variables in development of an archaeological predictive model

T.F. Bullard and E.V. McDonald (Desert Research Institute)

The advent of geographic information systems (GIS) and rapidly expanding databases has resulted in numerous data-rich GIS models for archaeological resource prediction (e.g. Altschul et al., 2004). As noted by Altschul et al. (2005), however, few, if any models consider the relations between archaeological resources and geology, geomorphology, soils, and landscape history. This first presentation described the approach taken in developing a landform-based predictive model for an area of the U.S. Army National Train-

Figure 1. Examples of associations among geology, landforms, and archaeological sites at Fort Irwin: surface stone ring and lithics imbedded in well-developed desert pavement (top); pediment surfaces (middle and cavernous weathering (tafoni) features (bottom) form natural shelters in areas underlain by quartz monzanite (from McDonald et al., 2004).

ing Center, Fort Irwin, California (McDonald et al., 2004). Compared to models based on physical environmental parameters (e.g., water resources, vegetation, slope, aspect), a landform-based model has the advantage of being able to integrate data on soils, surface processes, landform evolution, geology, and environmental factors. The main focus of the study was to identify possible relations among (1) key soil and geomorphic attributes; (2) landscape history; and (3) location of cultural resources. Fort Irwin was a favorable study location because it contains many recorded prehistoric sites located in a variety of geologic and geomorphic settings (Fig. 1), yet large areas have not been surveyed. A geomorphic and geologic evaluation of the recorded sites presented a unique opportunity to develop a geomorphic construct to relate different landscape parameters to a diversity of archaeological sites. This was achieved through (1) characterization of the geology, geomorphology, and soils at known archaeological sites of different types; (2) determination of site favorability based on site type, site age, cultural affiliation, geology and geomorphology, and environmental setting of the resources on the landscape; and (3) development of an understandable system for ranking site potential—for example, highly favorable to unfavorable—for each landform type and age. By examining the relationships among the geologic and geomorphic variables, and the frequency of archaeological sites, five variables (deposit age, surface age, bedrock or deposit lithology, landform morphology, and soil type) were determined to be correlative with archaeological site occurence.

The preliminary model was tested by making general predictive assessments for 150 survey blocks (0.5 km x 1.0 km) prior to contracted pedestrian surveys. Each block was categorized as having low, medium, or medium to high site potential. During the subsequent ground survey, sites were found in 29% of the blocks that were categorized as having a low site potential, in 25% of those given a medium site potential, and in 80% of those given a medium to high site potential.

Overall, the study showed that there are strong linkages between different cultural resource site types and certain soil-geomorphic and geologic variables. It also highlighted that a critical requirement for application of a landform-based predictive model is availability of detailed Quaternary geology and geomorphology maps.

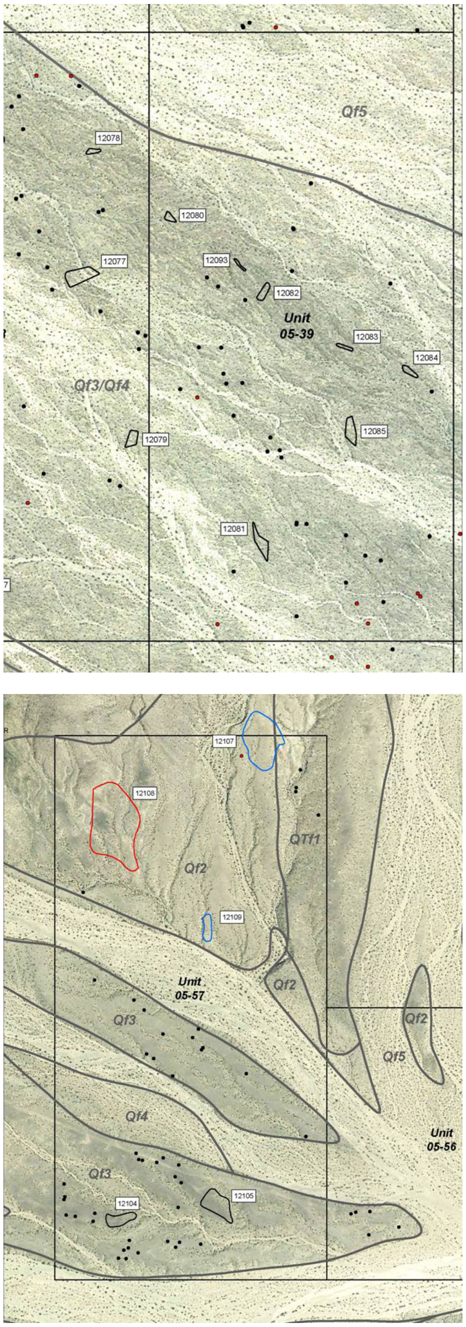


Figure 2. Archaeological sites (dots and small polygons) shown on a portion of an image for the Ft. Irwin Avawatz expansion area (top). The same sites superimposed on a surficial geologic map showing the association of sites with alluvial fan surfaces characterized by well-developed desert pavements (bottom) (from Byrd et al, this workshop).

Session I, Presentation 2

Logistical mobility, pavement quarries, and Gypsum period residential stability in the Mojave Desert: A case study at Fort Irwin

B. Byrd, D.C. Young, and K. McGuire (Far Western Anthropological Research Group, Inc.)

This presentation summarized a study focusing on Gypsum period pavement quarries and secondary quarries—consisting of multiple

segregated lithics reduction locales (SRLs)—in the 7000 acre Avawatz-East Gate Expansion area of the U.S. Army National Training Center, Fort Irwin. Because SRLs are typically characterized as single use sites, in contrast to long-term quarry sites, they represent precise moments in time. A simple, conceptual model based on the strength of desert pavement development on alluvial fan surfaces was used to predict the location of pavement quarries. The hypothesis of the model was that older geomorphic surfaces have well developed desert pavements and are likely to have a greater number and diversity of SRLs due to the longer period available for assaying and usage, and recent surfaces will have fewer quarries due to the limited prehistoric time window.

Pavement strength was used to discriminate and map alluvial surfaces (Fig. 2) and to make inferences about surface age and develop a local fan stratigraphy. Pockets of pack rat middens found in the walls of incised alluvial fan deposits helped in developing a geochronology, which provided bracketing ages of the fan units and established the relationship between surface age and occurrence of secondary quarries.

Session I, Presentation 3

Fort Irwin's archaeological model and its applicability

L. Ramirez de Bryson (U.S. Army, Fort Irwin Cultural Resources Department)

An APM initially developed for Fort Irwin by Tad Britt (Ruiz et al., 2002, 2007) at U.S. Army Corps of Engineers, Engineer Research and Development Center-Construction Engineering Research Laboratory (ERDC-CERL, Champaign, IL) was applied in a 120,000 acre Fort Irwin expansion area (Fig. 3). The vastness of the area necessitated an approach based on a focused, time-efficient survey to fulfill the requirements of Section 106 of the National Historic Preservation Act (NHPA).

The ERDC model predicted cultural sites based on physical environmental variables that included distance to water, soil texture and water content, depth to bedrock, elevation, slope, and aspect. Types of cultural resources considered by the model included habitation sites, lithic scatters, rock shelters, rock art, and historic sites.

Dr. Ramirez de Bryson refined and tailored the ERDC model by adding relevant data layers including geology to indicate availability of lithic materials, and fluvial maps and geomorphic data to help predict site distribution, depth, age, and integrity (Fig. 4). The model also was adjusted to be a more effective management tool by integrating maps of probable training land use with site potential maps. Future high use and high impact training areas intersecting areas with a high site potential could be given the highest priority and subjected to the most thorough survey methods.

The modified model was found to be very effective at predicting lithic scatters, quarries, lithic

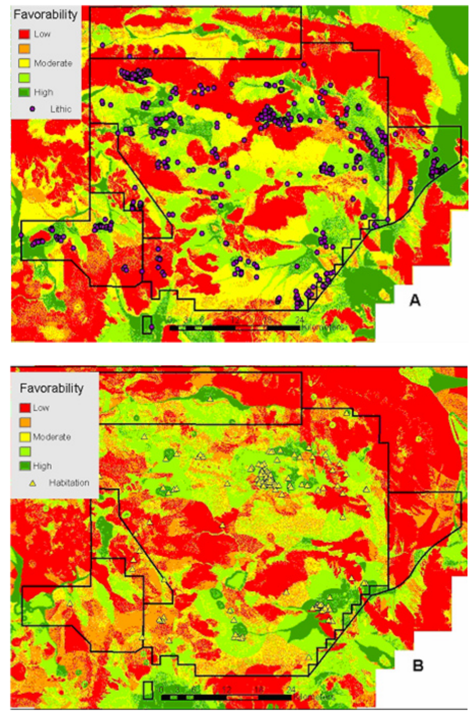


Figure 3. Models developed by the Army Corps of Engineers depicting favorability for lithic (top) and habitation (bottom) sites (from McDonald et al., 2007; Ruiz et al., 2007).

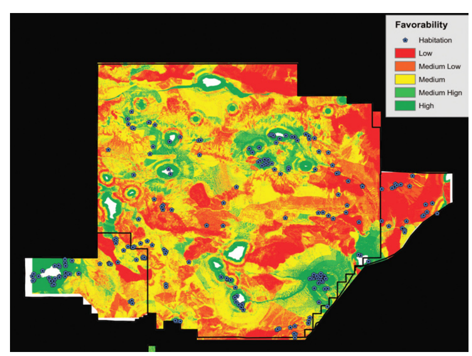


Figure 4. ERDC predictive model modified by Fort Irwin Cultural Resources Department to include additional geologic, geomorphic, and environmental layers (from Ramirez de Bryson, this workshop).

reduction sites, and habitation sites and was considered to be effective at streamlining Section 106 compliance work. An added benefit was that regulatory bodies (e.g., the State Historic Preservation Office) appeared to be comfortable with the model approach because of the field-testing and successful implementation.

Session I Discussion

Discussion focused on the potential benefits of predictive modeling, the potential advantage of geomorphic-based models compared to physical-environmental-parameter-based models, challenges, delays and limitations to the use of models, scale and model type, and future research avenues to pursue.

Potential of APMs to aid cultural resource management activities: It was universally agreed that models have the potential to benefit cultural resource management, especially in terms of streamlining Section 106 compliance work and reducing the amount of ground surveying. Both Drs. Ramirez de Bryan and Young felt their projects benefited greatly from APM use. In addition to compliance issues and time savings, APMs have great potential for project planning and budgeting, as well as for providing a useful framework for data presentation and knowledge transfer among colleagues and to successors. APMs also comprise an invaluable cultural resource management tool for inaccessible lands, where other research methods such as ground surveys are not possible.

Challenges facing development and implementation of APMs: Given the amount of expressed acclaim and interest in APMs, the question arose as to why so few DoD cultural resource managers employ APMs. One reason expressed was the relatively low level of funding for development and testing of these models. Even though APMs have great potential to reduce the cost of compliance-driven surveys in the long run, their development generally requires a large initial investment in time and money. Because of the backlog of unsurveyed land and historic properties requiring assessment, as well as rapidly changing training schedules and range usage, most projects require quick attention—which results in project-by-project funding commonly tied to other projects that have compressed timelines. Although an APM was used to address the Fort Irwin expansion, that case comprised a somewhat exceptional set of circumstances. The process of acquiring a very large area of land is slow, and this expansion compromised a high-stakes gain for the U.S. Army. Consequently, time and money were available for APM development. One suggested approach to overcoming this roadblock is to make future APM development part of a larger overarching project funded by a program structured to fund research and development of tools for cultural resources management, such as ESTCP/SERDP, Legacy

Resource Management Program, or other significant sources of cultural resources management and research funding.

Appropriate scale, universality, and geographic breadth of an APM: With any modeling attempt, model scale must be suitable for the problem being addressed, the desired geographic range, and the available data. Cultural resource managers among the group expressed concern that the broader the model scale, the less useful it would be for an individual installation. The principal reason cited for the concern is that archaeological sciences are less controlled by universal rules than are physical sciences: cultural resources data are esoteric, in large part because human activity is influenced by local historical events in addition to local geologic and environmental conditions.

In response to this, it was proposed that a multi-layered model based on geomorphic and geologic parameters ultimately could have universal application, because of the basic predictable linkages between climate, geomorphic processes, and human activity. A model having a universal foundation was desirable because it could allow for improved consistency and communication between installations and bestow the model with more credibility; however, it was widely expressed that in order to meet project objectives and local conditions, the model must retain sufficient flexibility to accommodate additional data, such as locally esoteric or ethnographic data, and the ability to adjust the weight of variables.

Appropriate form of an APM: Many types of models can be developed and applied. Regardless of the model type, however, it must be compatible with the purpose and available data. Two basic model types discussed were numerical and conceptual. Numerical models can be manipulated to each specific investigation by changing input data. Keeping in mind the need for model approval by CRM personnel, land owners, and regulatory agencies—and although some of these parties may find a numerical model more credible because of the perceived objectivity that it offers—the majority of workshop participants seemed to agree that a more transparent, conceptual model would be more accessible and favorably received. Furthermore, the appropriateness of a numerical model is questionable given that typical geomorphic and archaeological data are more esoteric and location-specific than the rules that govern physical and chemical processes.

The geoscientists in the group supported a conceptual model approach, and noted that good conceptual models and understandings of the relationships are prerequisites for numerical models; however, for the desert Southwest even conceptual models are not yet in place. The attractiveness of geomorphic conceptual models is the flexibility, understandability, and effectiveness offered. An example would be the state fac-

tor approach in soil formation, which relates five environmental and geologic parameters to soil characteristics at a location; the same five parameters apply at all locations, but the parameters typically receive different weightings to reflect the most important local factors. The result is a conceptual model of soil formation under various settings and conditions from which numerical models have been developed to isolate and characterize specific factors that drive soil development.

Recommendations for Moving Forward with APMs

a) Gain approval by regulatory bodies

If APMs are to be implemented successfully in compliance work, their use must be accepted and encouraged by regulatory bodies, especially if modeling results are to be used in lieu of field surveys in certain areas. Prior experience suggests that approval from regulators may be likely if the following conditions are met:

- All parties recognize that an APM is a tool to guide or focus field surveys.
- An APM is not intended to replace other methods of archaeological survey.
- An APM always must be used in combination with other methods.
- The APM is field tested to confirm accuracy prior to being employed as a decision making guidance tool.

Incorporating CRM mission objectives and land use objectives into the models, as was done in the Fort Irwin expansion area, is also an effective approach at focusing ground surveys and may increase chances of approval of the model-based approach. Inclusion of APMs into DoD Integrated Cultural Resource Management Plans (ICRMPs) may help to expedite APM development and acceptance; however, it was noted that inclusion of an APM also could create, unnecessarily, an extra burden for cultural resources managers, especially in areas where an APM cannot be used effectively.

b) Improve input data

Beyond the initial data needed to determine the relationships between geomorphic variables and archaeological variables, a geomorphic-based model will only be effective if there is geomorphic and soil mapping data for the unsurveyed area of interest to input into the model. Methods for rapid geomorphic and soil mapping are being developed and implemented by a team of geomorphologists at DRI and could be adapted and used to map areas requiring cultural resource inventorying.

c) Adopt objective terminology

In order to establish and predict linkages between geomorphic and geologic variables and archaeological site occurrences, data must be expressed in terms that are as consistent, specific, and objective as possible. Much existing archaeological data, especially earlier survey data, are recorded in subjective terminology. Deter-

mining the strength and reliability of existing data is necessary to avoid developing tenuous or inaccurate model linkages and hence faulty interpretations. Therefore, it was recommended that definitions and nomenclature are carefully considered when defining model parameters for any APM.

Session II

Detection of Buried Site -- Methods, Approach, and Practice

Introduction to Session II

A buried archaeological site comprises material evidence of human activity that is buried either by anthropogenic or natural depositional processes. Cultural resource management challenges relating to buried sites include finding sites that are not evident from surface inspection alone, interpreting site context (e.g., in situ or reworked), and interpreting site paleo-environment. Topics and questions open for discussion regarding buried sites included:

- How can soils and geomorphology help address buried site concerns? Is better stratigraphy needed? Are facies (sedimentary) models adequate?
- What geomorphic concepts could be implemented to address buried sites? Are there new research directions to pursue? Does geomorphology assist in compliance and meeting mission objective?
- What is the best way to accomplish technology transfer: workshops, papers, training sessions, application?

Session II, Presentation 1

Application of methods to detect buried sites at MCB Camp Pendleton, San Diego County, California

[1]S. Berryman and [2]M. Becker ([1]U.S. Marine Corps Base Camp Pendleton, [2]ASM Affiliates)

This presentation described the investigation of buried sites on Camp Pendleton along the San Diego County coast at the mouths of San Mateo and Las Flores creeks and the San Luis Rey River. The project demonstrated the effectiveness of collaboration between archaeologists and geomorphologists in reconstruction of paleo-environment conditions in dynamic geomorphic settings such as these, as well as the application of methods used for subsurface investigations including mechanical drilling, ground penetrating radar (GPR), and seismic shear-wave velocity.

Sedimentology data obtained from 50 drill cores at Las Flores Creek were incorporated into a three-dimensional (3D) model of depositional units (Fig. 5). Data on the artifacts found in each core were superimposed on the stratigraphic data to help define surfaces of human occupation. Artifact distributions suggested repeated short-term occupations resulting in small specialized sites in contrast to an intense occupation that would result in a large site on a single surface. At the San Mateo Creek and San Luis Rey River study areas, GPR was employed

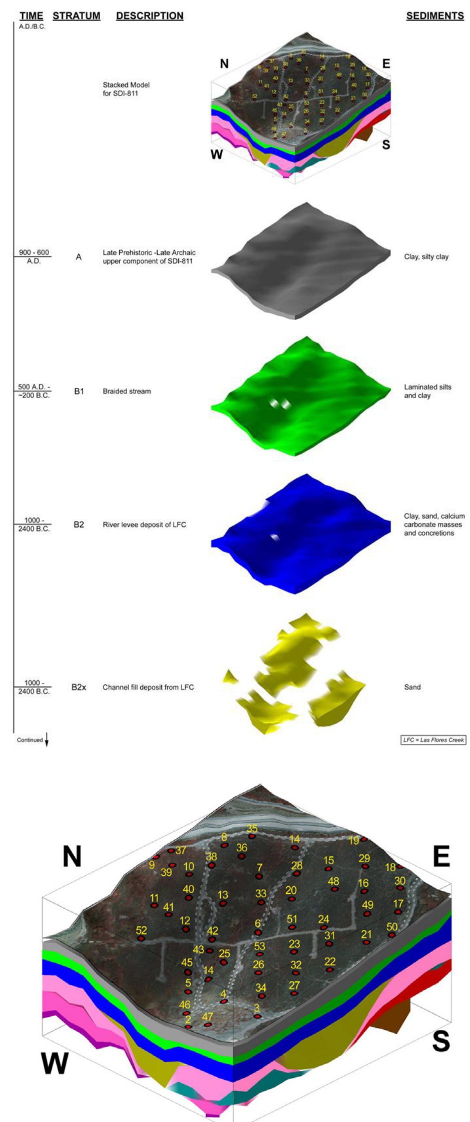
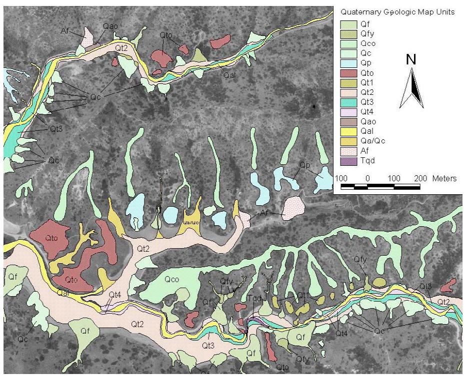
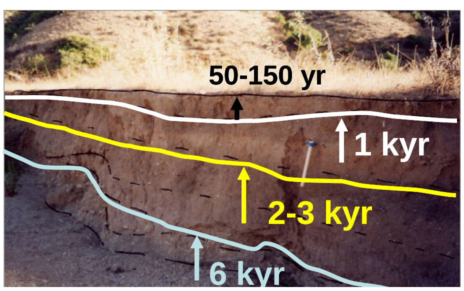
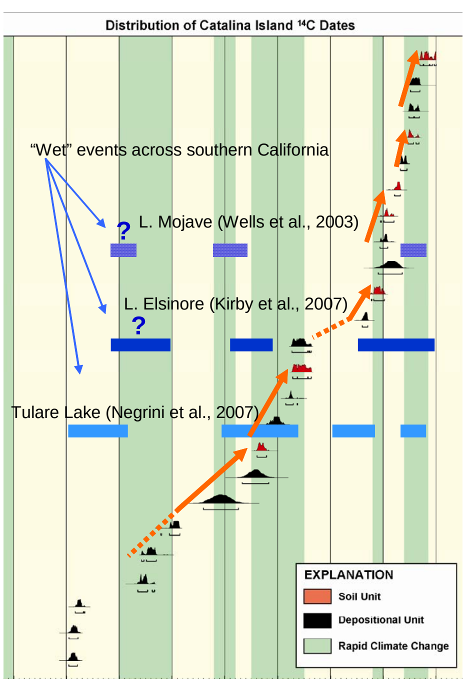


Figure 5. Examples of paleo-landscape reconstructions derived from drill-hole and GPR data (from Berryman and Becker, this workshop).







to identify buried geomorphic features, namely high energy fluvial channels—features unlikely to contain in situ archaeological materials, but key in providing data for paleo-environmental reconstructions that helped to focus research efforts.

Session II, Presentation 2

Integrating soils and geomorphology to understand landscape evolution and geomorphic response to changing environment in a coastal Mediterranean setting

E.V. McDonald and T.F. Bullard (DRI)

This presentation provided an example of a soils-geomorphic study with potential application to investigations of buried archaeological sites. The study had the goal of reconstructing the landscape evolution and fluvial history of a portion of Santa Catalina Island and relating the stratigraphic record with global climate change records (McDonald and Bullard, 2008). Developing a stratigraphic framework of the Holocene deposits was aided by an abundance of buried soils and datable materials in fluvial deposits that indicated multiple episodes of deposition during the Holocene, separated by periods of stability or erosion. Comparison with published data on the timing of rapid global climate change events suggests that there is an association between periods of deposition on Catalina Island and Late Holocene periods of pluvial lake activity in the Mojave Desert (Fig. 6). The study is relevant to archaeological work because it demonstrates the potential to define former habitable land surfaces, provides insight into the duration of surface stability, elucidates paleo-environmental conditions, and suggests correlations between local and global climate change events.

Session II Discussion

Discussion on the topic of buried sites focused on using geomorphic data to identify landscape components susceptible to deposition and burial with preservation, and addressed usage of geomorphic data to interpret the context, age, and paleo-environment of cultural resources once archaeological sites are located.

Predictive modeling of buried sites: Understanding geomorphic processes and principles of landscape development are essential to predicting where in the landscape burial and preservation of archaeological sites is most likely. The group expressed great interest in, and general acceptance of, using geomorphic concepts and data to predict the location of buried sites.

The age of surface deposits and the energy of depositional environments were suggested by many as important bases for predicting buried sites. The importance of buried soils as stratigraphic marker horizons indicating discrete periods of landscape stability, and as relative age indicators for developing stratigraphic and contextual chronologic frameworks, could not be overstated.

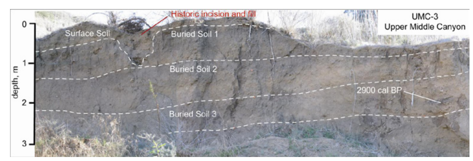
Suggestions for future research included developing a simple

preliminary geomorphic model for predicting buried site occurrence. Such a model could be as simple as a list of geomorphic processes that result in site burial, descriptions of where these processes are likely to occur, and how to recognize them. Examining the geomorphic context of known buried archaeological sites is necessary to enhance and validate the simple concept that the age of surficial deposits and the energy of depositional environments exert influence on the burial and preservation of archaeological sites. Despite apparent simplicity in concept, how the energy of depositional environments affects cultural resource sites in desert settings is a potential area for future research.

Paleo-environmental reconstruction, stratigraphy, and facies models: In addition to developing conceptual models for buried site location, detailed studies of stratigraphy and reconstruction of paleo-environment are fundamental for predicting the location of buried sites and for in-site context interpretations. Although archaeologists are often tasked to survey small areas in isolation, many projects benefit from the broader perspectives of expanded local and regional stratigraphy and geomorphic data. The simple understanding of facies (depositional) models and spatial variation in geomorphic processes and responses can enhance understanding of the distribution and age relationships of archaeological sites, a point emphasized by direct experiences of several workshop participants.

Geomorphic processes in coastal settings: Many workshop participants felt that a better knowledge of coastal geomorphic processes could benefit their understanding of the location and preservation state of cultural resources in coastal settings. Examples and discussion included coastal erosion on San Clemente Islands and other Channel Islands, as well as estuarine settings, and how greater geomorphic awareness contributes to coastal archaeology.

Understanding desert pavements: Desert pavements are prevalent in much of the U.S. Southwest and play a significant role in understanding the archaeology of desert regions. Knowledge of desert pavement formation processes and controls on pavement stability is important for predicting site location and for site interpretation. Group discussions suggested that the most recent knowledge concerning desert pavement formation may not have been communicated effectively to the archaeological community. Pavements can be excellent local relative age indicators, but their use as an absolute age indicator is currently limited by the lack of a reliable method for numerical dating of these features. However, workshop participants are aware of various attempts to date pavements as well as promising X-ray fluorescence (XRF) techniques being applied to dating petroglyphs (e.g., Lytle et al., 2008).



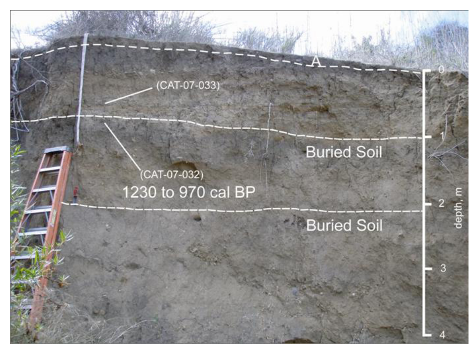


Figure 6. Examples of geomorphic mapping (page 18, top left) and stratigraphic analysis on Catalina. Chart shows distribution of radiocarbon dates and periods of moister regional climate (horizontal blue bars) and global climate change events (vertical green bars). The soil geomorphic history, as recorded in stream deposits and valley side tributaries, demonstrates the linkages between climate events and documented geomorphic events. Combined with mapping and stratigraphy this provides insight into potential zones of buried cultural materials (from McDonald and Bullard, 2008).

Overall, the long-term stability of desert pavement surfaces is generally accepted, although local surface disturbances from biologic activities (e.g., plants, animals, and burrowing insects) and surface runoff events can affect surface integrity. Earlier in the discussion on buried sites, it was mentioned that well developed desert pavement surfaces of Pleistocene age are unlikely to bury archaeological sites simply because they predate human presence in the Americas. It is well known, however, that pavements may recover, or heal, from surface disturbance relatively quickly, so that seemingly intact well-developed pavements could contain cultural resources that were buried beneath the surface by humans (see Lawson and Schaefer, this workshop) or by natural processes (e.g., Ahlstrom and Roberts, 2001). Nevertheless, simply associating healed pavements with archaeological sites is not valid without properly documenting the geomorphic and soils context at these sites.

Chronology of buried sites: Geomorphic techniques, and soils experience and expertise are essential to establishing the chronology of buried sites for the simple fact that age control for buried sites is commonly derived from the chronology of associated geological material. Numerical ages, though highly desirable, require careful interpretation within the context of the dated material and its relationship to the buried site, thus requiring a solid understanding of the soils and stratigraphy.

Furthermore, obtaining numerical ages for landforms and deposits is a challenge in desert environments due to the poor preservation of datable organic material. Various luminescence dating techniques (e.g., TL, OSL, IRSL) may be the most effective ways to date Holocene deposits but they can be slow and costly. Therefore, relative ages derived from a detailed assessment of site context and related soils may provide the best indication of relative age in the absence of datable material (e.g. McDonald et al., 2003).

Other non-invasive techniques useful for finding buried sites: Participants expressed a need to be aware of other research methods or emerging geophysical techniques currently in use by geoscientists that have yet to be exploited for cultural resources management. Although it is known that remote sensing techniques are unable to penetrate deep enough to be of widespread direct use to archaeologists, some techniques, such as high resolution light detection and ranging (LIDAR) and ground penetrating radar (GPR), may be used to detect surface and shallow subsurface disturbances, respectively, and such disturbances may be useful for identifying locations where humans have buried materials. At present, remote sensing is probably most beneficial to CRM in the production of bedrock and landform maps, as well as other physical parameter maps, which can be used to make predictions of site and buried site locations.

Recommendations for Buried Sites

The workshop participants agreed that the transfer of knowledge between archaeologists and geoscientists is highly important and will have an immediate impact on CRM practices relating to buried sites. Knowledge and technology transfer can occur in a number of ways, such as the following:

- Holding additional workshops
- Educational training sessions
- Mini field schools.

In general, though, a greater emphasis on collaboration between archaeologists and geoscientists is considered highly important and can serve as an effective means in transferring knowledge and technology.

Session III

Surface Features – Distinguishing Natural from Man Made Features

Introduction to Session III

The challenge to interpreting various types of surface features (e.g., trails, rock alignments, geoglyphs, and cleared circles) is determining unequivocally whether such features are anthropogenic or formed by natural processes. Identifying and interpreting surface features requires consideration of both natural and anthropogenic origins, thus requiring collaborative efforts among archaeologists and Earth scientists. Furthermore, distinguishing between anthropogenic and natural features is critical for forward progress in both areas of research.

Topics and questions open for discussion with regard to surface features included:

- Where and how can soils and geomorphology enhance our understanding of or help address surface features?
- What geomorphic concepts and research methods could be implemented to help interpret surface features?
- What is the best way to accomplish knowledge transfer?

Session III, Presentation 1

Introduction to prehistoric anthropogenic surface features in the desert southwest

[1]J. Lawson and [2]J. Schaefer ([1]U.S. Marine Corps Air Station, Yuma; [2]ASM Affiliates)

Jan Lawson spoke briefly about her work in the Chocolate Mountains and the Barry M. Goldwater West Range, describing the principal cultural surface features in these areas as trails, cleared circles, and bedrock water tanks (tinajas). Consideration of geomorphology may help with interpretation of these features as well as with locating other surface features; in terms of management, however, according to Ms. Lawson, geomorphology is not currently written into the Marine Corps Air Station Yuma (MCASY) regional research design. Adding to the challenge is that the MCASY ranges are situated in both Arizona and California, which treat the occurrence of surface features in different manners.

Jerry Schaefer provided an introduction to a range of prehistoric anthropogenic surface features in the desert Southwest and studies of them, focusing on features found along the Camino del Diablo trail, Pilot Knob lithic reduction sites and geoglyphs, and buried features along the Orocopia Mountains and Lake Cahuilla. Interpretations of all these features were enhanced or confirmed using geoarchaeology. The Camino del Diablo, a prehistoric Native American trail still in use, contains important archaeological evidence related to the history of contact between peoples of Sonora and the Lower Colorado and Gila areas. An understanding of relative surface age and cross-cutting relationships of landforms was crucial to this study, but involvement of a geomorphologist was not budgeted; thus, pre-existing geomorphic data from a study in a nearby area (Lashlee et al., 2002) was used as a source of data. With regard to prehistoric trails, a great challenge in interpreting them is the matter of distinguishing wildlife and livestock trails from human-made trails (e.g., Dore and McElroy, 2006; Becker and Altschul, 2003).

An additional side discussion involved verifying human utilization of lithic resources found on the surface of fluvial deposits exposed on terraces. In the cited example, straightforward stratigraphic principles and sedimentology were used to show that unaltered, fluvially transported clasts found in the subsurface had the same lithology as surface clasts that displayed breakage consistent with human utilization, thereby supporting the idea that the broken cobbles were anthropogenic. In this example, relatively simple geologic principles were employed to bolster the sparse archaeological evidence and lend greater strength to the archaeological interpretation and record.

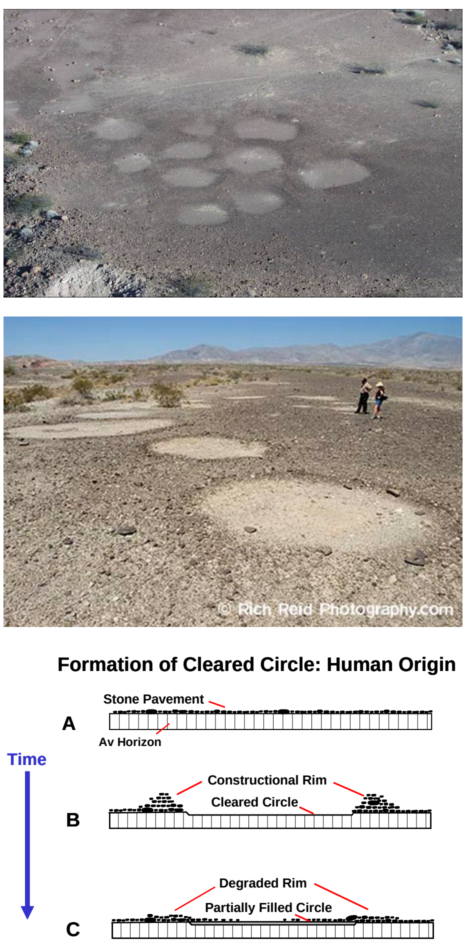


Figure 7. Photo examples of cleared circles at Yuma Proving Ground and cartoon depicting the surface evolution of a cleared circle over time (from McAuliffe and McDonald, 2006; McDonald et al., 2001, this workshop).

Session III, Presentation 2

Anatomy of a cleared circle at Yuma Proving Ground: a soil geomorphic approach

E.V. McDonald, [1]F. Briuer, [2]J. McAuliffe ([1]USACE Waterways Experiment Station; [2]Desert Botanical Garden)

This talk described an investigation of cleared circles, also known as sleeping circles, on desert pavement surfaces (Fig. 7). These features of uncertain origin are prevalent on desert pavement surfaces across the U.S. Southwest and northern Mexico. Many have been recorded as cultural features, attributed to deliberate scraping of the desert pavement by prehistoric inhabitants to create a more comfortable living (sleeping) surface (Dosh and Marmaduke, 1992; Marmaduke and Dosh, 1994; SAA, 2005). Alternatively, some cleared circles have been shown to result from biologic and pedogenic processes (McDonald et al., 2001; McAuliffe and McDonald, 2006).

Cleared circles are roughly circular in shape, 1-3 m in diameter, smooth, or with a shallow depression, and are either devoid of pavement clasts or have some weakly varnished clasts (notably weaker pavements than those ob-

served on the adjacent land surface). Common to many areas of cleared circles are active and relict shrub mounds similar in many respects to cleared circles suggesting a possible link between these features.

The study hypothesized that detailed characteristics of man-made and natural cleared circles would differ and could be used to distinguish them and, in turn, enable development of a model for the evolution of naturally formed cleared circles. Detailed analysis of the soils and surface morphology of cleared circles, active shrub mounds, and World War II bivouac sites (i.e., pavement areas cleared by soldiers) located on alluvial fan surfaces at the U.S. Army Yuma Proving Ground revealed obvious, measurable differences in surface morphology and the integrity and composition of subsurface soil horizons between the anthropogenic and naturally formed features.

These results, as well as observations of the apparent regular spatial distribution of cleared circles, indicate that most of the cleared circles at YPG probably were created by long-term interactions between desert shrubs (e.g., creosote bush) and small burrowing mammals (e.g., rodents) that tend to inflate the area and disrupt pavement formation and pedogenesis (Fig. 8). Although the study concluded that many of the cleared circles recorded at YPG may be natural phenomena, the age and distribution of these features may hold important information about changing environmental conditions and may record long-term trends in regional climate. Therefore, despite the potential for losing their status as cultural resource sites, cleared circles still hold important data for interpreting human occupation of the area. Furthermore, the conclusions of this study do not preclude the existence of human-made cleared circles, nor the modification or utilization of plant scars by prehistoric inhabitants.

Session III Discussion

A lively and extended discussion following these presentations suggested that research on surface features will benefit greatly from the collaboration and transfer of knowledge between archaeologists and geomorphologists. Both fields of research would benefit from such collaboration, especially on the issue of cleared circles.

Distinguishing natural and cultural cleared circles: Cleared circles do not occur across the entire desert Southwest but are very prevalent in the Sonoran Desert and parts of the Mojave Desert. A large number of cleared circles have been recorded as cultural features (e.g., Dosh and Marmaduke, 1992), although current evidence suggests a non-anthropogenic origin is probable for most if not all such features. Although their interpretation as cultural features was made in good faith, workshop participants agreed that including a large number of non-cultural features in the archaeological site inventory is a burdensome impediment for land managers and

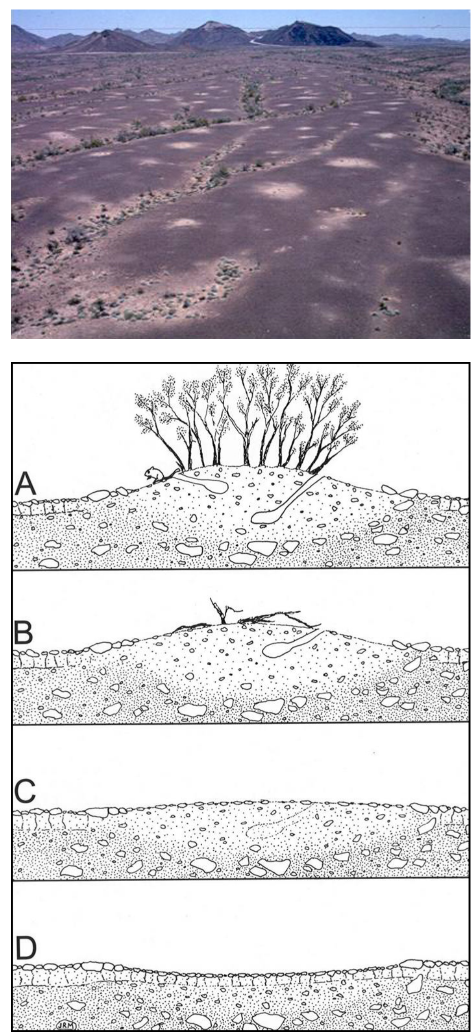


Figure 8. Photo examples of plant scars at Yuma Proving Ground and cartoon depicting biologic processes involved in their evolution (from McAuliffe and McDonald, 2006; McDonald et al., 2001, this workshop).

Figure 9. Photographs showing stone alignments in desert pavements at Fort Irwin. Although interpreted as geoglyphs, origin has not been confirmed—although neither human nor natural causes can be ruled out (Luz Ramirez de Bryson photos).

archaeological researchers, as well as for geomorphologists who recognize natural cleared circles as insights into past environmental conditions.

By consensus, the group proposed that a protocol be developed for differentiating natural and manmade cleared circles during field surveys. It was emphasized that this should be something that could be utilized by field technicians during the first stages of survey, so that the tendency to incorporate natural features into the cultural resource inventory would be discouraged. The protocol should be based on knowledge of all types of anthropogenic cleared circles (e.g., sleeping or dancing circles, water holes, house or fire pits, meditation circles) and all possible non-anthropogenic origins (e.g., plants scars, animal wallows). The group agreed that the protocol should be based primarily on observations that can be made without excavation—including surface morphology, spatial distribution, and landform association—so that as much data as possible can be gleaned during initial field surveys. The survey protocol would also indicate when subsurface testing might be required to make the discrimination. One idea proposed was that the protocol could include rating the feature in terms of its probability of being cultural. One question posed was whether such a protocol could eventually evolve into a method for determining relative age, as well as origin, but this was deemed to be unfeasible because cleared circles of different origins likely would evolve differently through time. A differentiating protocol also could be utilized to revisit previously recorded cleared circles in order to reduce or eliminate the legacy of false data in the expanding archaeological record.

Prior to incorporating a new protocol into survey practices, the protocol would need to pass scrutiny, approval, and acceptance by Native American groups and regulatory agencies. Replication studies might provide a test of discriminating factors. Excavation and detailed analysis of the morphology and soils of a selection of cleared circles that spans the range from definitely natural to definitely cultural would comprise a valuable future study and would help in development of an effective protocol. Furthermore, cleared circles confirmed to be cultural would be of significant new interest given the assumption that most circles are natural in origin. This would open new and intriguing arenas of research and inquiry for these otherwise low-interest features.

Improved understanding of geomorphic processes: There also was strong consensus among the geoscientists and archaeologists that knowledge of geomorphic processes would help greatly with recognition and interpretation of surface features. Distinguishing cultural features such as rock alignments, bedrock mortars, trails, and worked pebbles from naturally formed features is not a simple task (Fig. 9). For example, failure to recognize natu-

rally formed features such as rock alignments associated with debris flow levees, bedform features (ripples and dunes), desiccation cracking, bedrock weathering features, fluvially formed scour holes (frequently mistaken for bedrock mortars), and clasts fractured by natural sediment transport mechanisms can lead to misleading interpretations.

How to achieve knowledge transfer: Given the desire and need for exchange of knowledge between geoscientists and archaeologists, there was strong interest in establishing a working group (with participants of this workshop as the core members), and in this group holding training classes on geomorphology for archaeologists, and vice versa. It was suggested that the working group should hold additional workshops in the future and that workshops and training classes would benefit from inclusion of a field component.

additional discussion

A time slot was set aside for workshop participants to provide comments or initiate discussion on additional topics not addressed in the formal sessions. The discussion centered primarily on the following mutually beneficial needs:

Ways that archaeologists can help geomorphologists-

- In understanding the rate of formation of young soils and disturbed soils. Archaeologists often work at sites where there are young and/or disturbed soils (i.e., those that cover buried sites) and often have good age control for the soils. An example of soils that may be of interest to geomorphologists for this type of study are those that bury pit houses and fish weirs in the Salton Sea area.
- In studies of active tectonics. Cultural data can be used to date fault offset and springs located along faults.

Ways that geomorphologists can help archaeologists –

- In understanding the effects of tsunamis on the preservation of coastal cultural resources.
- In determining site formation processes.
- In understanding landscape responses to environmental change.

  Geomorphic and stratigraphic studies provide information about the climate record, which provides insight into human activity. Further geomorphic research is needed to better understand the temporal and spatial relationship between climate change and specific geomorphic processes such as sediment production, storage, and transport.
- Understanding the soils and stratigraphic context of numerically dated material to properly interpret the laboratory results.

final thoughts

Where to go from here?

There is a substantial benefit to be gained from collaboration among geomorphologists, Quaternary geologists, archaeologists, and cultural resource managers. On a fundamental level, the workshop indicated that archaeologists and cultural resource managers would benefit from overall greater knowledge of geomorphology, geology, and geological terminology. The geoscientists echoed this comment from the perspective of benefitting from a better understanding of archaeological prehistory and terminology. Furthermore, the application of geoarchaeology is not restricted to prehistoric sites. The time window offered by late prehistoric and historic sites commonly results in a short period for geomorphic processes that translates, in most cases, into sites having little to no stratigraphic depth. Although the relative youth of historic sites appears to restrict the utility of geoarchaeological methods, it is important to recognize that the geoarchaeologist is typically equipped to provide interpretations on site integrity in the present as well as identify potential operators that could impact future site integrity. Suggested ways to achieve improved collaboration among Earth science disciplines and the cultural resources community include:

- Develop and hold training classes on geomorphology for archaeologists.
- Incorporate a field component into future workshops.
- Strive for interdisciplinary projects rather than multidisciplinary. This fosters close communication and collaboration of multiple stakeholders in contrast with delegation of tasks to independently working research groups.
- Being aware that even though geomorphic maps are a valuable resource, proper interpretation requires continued collaboration with geomorphologists.

Areas of future research needs align closely with the workshop topics. In general, there is still much room for improvement and research within the three workshop topic areas.

Predictive modeling

- Interest is strong among archaeologists and CRM professionals in pursuing development and implementation of a conceptual, geomorphic-based APM for desert areas.
- A multi-installation effort to produce a widely applicable model has the greatest chance of coming to fruition.
- Good input data also will be necessary for successful model implementation.

Buried sites

- A geomorphic-based APM for buried sites is equally at-

tractive to cultural resource managers as is one for surface sites.

- A simple conceptual model for predicting buried site locations can be based on surface age and the energy of the depositional environment.
- Facies models, stratigraphic data, and paleo-environmental reconstructions are essential in finding and interpreting buried archaeological sites.
- Knowledge of desert pavement formation and the evolution of desert pavements is increasing, but a reliable method for obtaining numerical ages for these features has yet to be developed.

Surface features

- The group favors working toward developing criteria and protocols for distinguishing natural and anthropogenic features, especially cleared circles.
- A valuable future study would involve the soils and geomorphic analysis of a range of cleared circles of various anthropogenic and natural origins.

references

Ahlstrom, R.V.N. and Roberts, H., 2001, Desert pavement and buried archaeological features in the arid west: a case study from southern Arizona: Journal of California and Great Basin Anthropology, v. 23, p. 1-26.

Altschul, J.H., Sebastian, L., and Heidelberg, K., 2004, Predictive modeling in the military – similar goals, divergent paths. SRI Foundation Preservation Research Series 1, 43 p.

Altschul, J.H., Klein, T.H., and Sebastian, L., 2005, A workshop on predictive modeling and cultural resource management on military installations. Legacy Resource Management Program, Project #03-167. SRI Foundation Preservation Research Series 4, 27 p.

Becker, K. and Altschul, J.H., 2003, Historic context for prehistoric and protohistoric trails and related features at Yuma Proving Ground, Arizona. Technical Report 03-13, Statistical Research, Tucson.

Briuer, F., Brown, C., Gillespie, A., Limp, F., Trimble, M., and Richeson, L., 2000, Report proceedings: cultural resources management workshop, June 13-16, 2000, Patuxent River Naval Air Station, Lexington Park, MD. Project 00-101, DoD Strategic Environmental Research and Development Program and DoD Legacy Resource Management Program, 28 p. + 4 appendices.

Dore, C.D., and McElroy, S.A., 2006, Automated trail identification and mapping: an experiment in archaeological spectral-image analysis using commercial high-resolution satellite remote-sensing data. Technical Report 06-02, Statistical Research, Inc., Tucson, AZ, 8 p.

Dosh, S.G. and Marmaduke, W.S., 1992, Cultural resources inventory, Jefferson Proving Ground relocation, U.S. Army Yuma Proving Ground, Yuma County, Arizona. Northland Research, Inc., Flagstaff, AZ, report to Environmental Division U.S. Army Yuma Proving Ground, Contract. DAAD01-90-D-0220, 72 p.

Lashlee, J.D., Briuer, F, Murphy, W. and McDonald, E.V., 2002, Geo-

morphic mapping enhances cultural resource management at the U.S. Army Yuma Proving Ground, Arizona, USA, Arid Land Research and Management, v. 16, No. 2, p. 213-219.

Lione, B., 2007, DoD Cultural resources workshop: prioritizing cultural resources needs for a sound investment strategy. Department of Defense, 2007 Sustaining Military Readiness Conference, July 30th – August 3rd, Orlando, FL.

Limp, F., 2006, SERDP and ESTCP technologies for cultural resources detection. Legacy Resource Management Program, DoD Cultural Resources Workshop, July 11-13, 2006, Marriott Sea-Tac Airport Hotel, Seattle, WA.

Lytle, F., Lytle, M., Rogers, A., Garfinkel, A., Maddock, C., Wight, W., and Cole, C., 2008, An experimental XRF technique for measuring age of petroglyph production: results on Coso Petroglyphs. Symposium 3: Archaeology of China Lake, 31st Great Basin Anthropological Conference, Portland, Oregon.

Marmaduke, W.S. and Dosh, S.G., 1994, The cultural evolutionary context of sleeping circle" sites in the Lower Colorado River Basin. Northland Research, Inc., Flagstaff, AZ, report to Yuma Proving Ground, Yuma, AZ Contract DAAD01-90-D-0220, 199 p.

McAuliffe, J.R. and McDonald, E.V., 2006, Holocene environmental change and vegetation contraction in the Sonoran Desert. Quaternary Research, v. 65, p. 204-215.

McDonald, E.V., Briuer, F., and McAuliffe, J., 2001, Determining the cultural significance of cleared circles at Yuma Proving Ground. Army Research Office sponsored research.

McDonald, E.V., McFadden, L.D., and Wells, S.G., 2003, Regional response of alluvial fans to the Pleistocene-Holocene climatic transition, Mojave Desert, California, in Y. Enzel, S. G. Wells, and N. Lancaster, (eds.), Paleoenvironments and Paleohydrology of the Mojave and southern Great Basin Deserts. Geological Society of America Special Paper 368, p. 189-205.

McDonald, E., Bullard, T., Britt, T, and Ruiz, M.O., 2004, Development of an archaeological predictive model for management of military lands, in D.R. Caldwell, J. Ehlen, and R.S. Harmon, (eds.), Studies in Military Geography and Geology. Kluwer Academic Publishers, p. 259-270.

McDonald, E., Bullard, T., Britt, T., and Ruiz, M.O., 2007, Identification of geologic variables in developing an archeological predictive model for cultural resources management on military lands in desert terrain. Poster #30, Proceedings of the 2007 Sustaining Military Readiness Conference, Orlando, Florida.

McDonald, E. and Bullard, T., 2008, Holocene alluvial history derived from soil-stratigraphy, Santa Catalina Island, California. Geological Society of America, Cordilleran and Rocky Mountain Sections Annual Meeting, Abstracts with Programs, v. 40, No. 1, p. 89.

Ruiz, M.O., Britt, T., Gundrum, D.S., McDonald, E., and McTighe, T., 2002, Geostatistics for an archeological site potential model. ESRI International User Conference, San Diego, CA.

Ruiz, M.O., McTighe, T., Yang, S., Britt, T., Norris, D., McDonald, E., and Bullard, T., 2007, An archaeological predictive model for Fort Irwin, California: an approach to model development and technology transfer. Poster #71, Proceedings of the 2007 Sustaining Military Readiness Conference, Orlando, Florida.

SAA, 2005. Symposium 35: Circles, symbolism, and space: the distribution and meaning of circles in the archaeological and ethnographic records. Society for American Archaeology, 70th Annual Meeting, Salt Lake City, UT, abstracts.

Appendix

AGENDA

Integration of New Methods in Soils and Geomorphology Applied to Cultural Resources Management on Military Lands

20-22 October 2008

U.S. Army Research Office, Desert Research Institute &

U.S. Navy, Naval Facilities Engineering Command Southwest (NAVFAC SW)

Del Mar Room of the Bahia Resort Hotel, San Diego, California

Icebreaker Monday 20 October 2008

1830 - 2200	Hospitality suite

Day 1: Tuesday 21 October 2008

0800 - 0830	Arrival, registration, & continental breakfast (juice, coffee, fruit, pastries)
0830 - 0845	Welcome & Introductory Remarks - R. Harmon, Army Research Office
0845 - 0900	Introductions and format T. Bullard, E. McDonald (DRI), Darrell Gundrum (NAVFAC SE)
0900	Session I: Landform based predictive models
	a. – Overview and geomorphic approach: T. Bullard
	b. – Application of geomorphic based model at Ft. Irwin: L. Ramirez & C. Young (Fort Irwin Cultural Resources Department & Far Western Anthropological Research Group)
0945 - 1015	Mid-morning break (coffee & soft drinks)
1015 - 1150	Roundtable discussion
1150 - 1200	Session I Summary
1210 - 1315	Lunch (provided on the patio): deli style buffet
13:15	Session II: Detection of buried sites – methods, approach, & practice
	a. – Application of methods at Marine Corps Base Camp Pendleton - S. Berryman (USMCBCP) and M. Becker (ASM Affiliates)
	b. – Integrating soils and geomorphology to understand landscape evolution and geomorphic response to changing environment in a coastal Mediterranean setting – E. McDonald (DRI)
1400 - 1500	Roundtable discussion
1515 - 1530	Mid-afternoon break (refreshments & snacks)
1530 - 1645	Roundtable discussion continued

1645 - 1700	Session II Summary, daily wrap up, evening plan, outline for Wednesday
	Evening – Hospitality suite open following afternoon session
	Informal Group Dinner – World Famous on Pacific Beach Dr.

Day 2: Wednesday 22 October 2008

0800 - 0830	Arrival, continental breakfast
0830	Session III: Surface features – distinguishing natural from man made
	a. – Introduction to prehistoric anthropogenic surface features in the desert southwest – J. Lawson (MCAS Yuma) & J. Schaefer (ASM Affiliates)
	b. – Anatomy of a cleared circle at Yuma Proving Ground: a soil geomorphic approach – E. McDonald (DRI)
0930 - 1145	Roundtable discussion - mid-morning break
1145 - 1200	Session III Summary
1210 - 1300	Lunch (on the patio): San Diego Old Town Mexican style buffet
1300 - 1500	Open Forum, discussion
1500 - 1515	Mid-afternoon refreshments
1515 - close	Summary, next steps, closing remarks, and departure

Sunset Cliffs, San Diego, California,
October 2008